Is organic tuber production promising? Focus on implications, technologies and learning system development

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Abstract

Organic farming is an alternative for sustainable and safe food production. Tropical tuber crops, cassava, yams and aroids are ethnic starchy vegetables with good taste and nutritive value. Field experiments were conducted at Central Tuber Crops Research Institute, India, for a decade to compare the varietal response, yield, quality and soil properties under organic vs conventional system in tuber crops and to develop a learning system. The industrial and domestic varieties, the elite and local ones and the native and introduced species responded similarly.Organic management enhanced yield by 10-20%, net profit by 28%, improved the tuber quality with higher dry matter, starch, crude protein, K, Ca and Mg contents and lower anti-nutritional factors and promoted the physico-chemical properties, dehydrogenase enzyme activity and microbial count. A learning system was developed using artificial neural networks to predict the performance of organic system. Technologies are described.

Introduction

Presently world agriculture needs knowledge-intensive design to reduce the dependence on external fossil fuel inputs and enhance yield and access to food. Organic farming provides synergies between food production and ecosystem services and contributes to safe food and environment. Tropical tuber crops viz., cassava, elephant foot yam, taro and yams (*Dioscorea* spp.) are climate smart and food security crops for 500 million of the global population. These are high energy starchy vegetables with good taste and medicinal values. As these crops respond well to organic manures there is ample scope for organic production and export. The goals were to compare yield, quality, economics, soil physico-chemical and biological properties under organic vs conventional management in tuber crops by field experiments and to develop a learning system using artificial neural network to predict the yield of elephant foot yam under various organic input combinations in different locations of India.

Material and methods

Study site, experimental design, treatments and test variety

Seven separate field experiments were conducted at the Central Tuber Crops Research Institute, Thiruvananthapuram, India, over a decade (2004-2013) to compare organic farming over conventional system in cassava, elephant foot yam, taro and yams in an acid Ultisol (pH: 4.3-5.0). In cassava, the experiment was laid out in split plot design with three varieties, H-165 (industrial variety), Sree Vijaya and Vellayani Hraswa (domestic varieties) in main plots and five production systems, traditional, conventional, integrated and two types of organic in sub plots. The impact of conventional, traditional, organic and biofertilizer farming was evaluated in RBD in elephant foot yam. Comparative response of 5 varieties of elephant foot yam (Gajendra, Sree Padma, Sree Athira and 2 locals) under organic and conventional farming was also evaluated in another experiment. The three trailing genotypes of edible *Dioscorea* (white yam: *D. rotundata* (var. Sree Priya), greater yam: *D. alata* (var. Sree Keerthi) and lesser yam: *D. esculenta* (var. Sree Latha)) were evaluated under conventional, traditional and organic farming systems in split plot design. Likewise the response of three varieties of taro (Sree Kiran, Sree Rashmi and local) to the various production systems was studied. The dwarf genotype of white yam (var. Sree Dhanya) was also evaluated under conventional, traditional, organic and integrated systems in RBD. The organic farming technology developed for elephant foot yam (on station) was confirmed through on farm trials conducted at 10 sites covering 5 ha in Kerala under the project financed by National Horticulture Mission.

Chemical inputs were not used for an year prior to the start of the investigations. In "conventional plots" farmyard manure (FYM) + NPK fertilizers were applied. Farmers practice of using FYM and ash was followed in "traditional plots". In "organic farming plots", FYM, green manure, ash, neem cake and/or biofertilizers

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were applied to substitute chemical fertilizers. In “biofertilizer farming”, FYM, mycorrhiza, *Azospirillum* and phosphobacterium were applied. In “integrated farming“, FYM, chemical fertilizers and biofertilizers were

used. The NPK additions in the various treatments is given in Table 1. Organically produced planting material was used for the study. In this paper the comparison between organic and conventional treatments alone are discussed.

Plant and soil measurements and statistical analysis

Pooled analysis of yield data of 5 years was done. Proximate analyses of tubers for dry matter, starch, total sugar, reducing sugar, crude protein, oxalates and total phenols, mineral composition of corms viz., P, K, Ca, Mg, Cu, Zn, Mn and Fe contents, chemical parameters of soil viz., soil organic matter (SOM), pH, available N, P, K, Ca, Mg, Cu, Zn, Mn and Fe status, physical characters of the soil such as bulk density, particle density, water holding capacity and porosity, plate count of soil microbes viz., bacteria, fungi, actinomycetes, N fixers, P solubilizers and the activity of dehydrogenase enzyme were determined by standard procedures. Economic analysis was done. The analysis of variance of data was done using SAS (2008) by applying analysis of variance technique.

Table 1 : NPK additions in the various production systems

Crop	N: P_2O_5 : K_2O (kg ha^{-1})			
	Conventional	Traditional	Organic	Biofertilizers/Integrated
Cassava	163:75:135	74:57:177	245:83:249	110:55:128
Elephant foot yam	225:100:220	198:120:314	353:153:408	145:70:70
Yams	130:80:108	84:54:148	239:87:243	
Dwarf white yam	130:80:108	84:54:148	239:87:243	100:60:108
Taro	140:49:134	87:62:184	242:95:278	

Development of a learning system

A learning system was developed using artificial neural networks (ANN) to predict the performance of elephant foot yam production system (Frank Zee and David Bubenheim 1997, Rajasekaran and Vijayalakshmi 2009). A three layered system with one input layer, one output layer and a hidden layer was developed. There were 12, 3 and 4 neurons in the input, hidden and output layers respectively. The input layer neurons included temperature, rainfall, planting material, FYM, K, P, ash, neem cake, *Azospirillum*, phosphobacteria, mycorrhiza and green manure. The output layer neurons were total biomass, corm yield, canopy spread, plant height. Four datasets for the different years were used for training the system.

Results

Varietal response

The industrial and domestic varieties of cassava, the elite and local varieties of elephant foot yam and taro and all the three species of *Dioscorea* responded similarly to both the systems. However, the industrial variety of cassava, Gajendra variety of elephant foot yam and the trailing genotypes of *Dioscorea* yielded more under organic farming than chemical farming. The dwarf white yam produced slightly higher yield under conventional practice.

Yield and economics

Organic farming resulted in 10-20% higher yield in cassava, elephant foot yam, white yam, greater yam and lesser yam ie., 8, 20, 9, 11 and 7% respectively. In taro and dwarf white yam slight yield reduction was noticed under organic farming (2-4%) (Figure 1). The boxplot showing the distribution of yield of different crops under the organic and conventional production systems was drawn using R environment for statistical computing (R version 3.0.2, 2013) (Figure 2). Yield trend over 5 years and pooled analysis indicated the significantly superior performance of organic farming in elephant foot yam. In yams, up to third year, organic farming proved superior, thereafter it was on par or slightly lower than conventional practice. Pooled analysis indicated that organic farming was on par with conventional practice but with slightly higher yield. In taro, organic farming was on par with conventional practice, but chemical farming produced slightly higher yield. This was because taro leaf blight could not be controlled by organic measures. Cost-benefit analysis in elephant foot yam indicated that the net profit was 28% higher and additional income of Rs. 47,716 ha^{-1} was obtained due to organic farming (Suja et al. 2012).

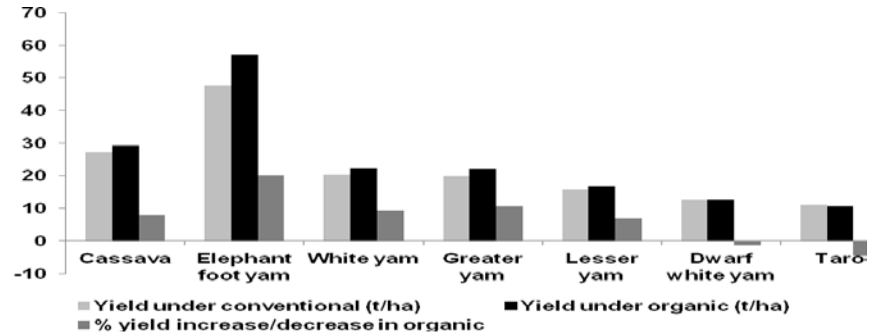

Figure 1: Organic vs conventional in tuber crops: tuber yield

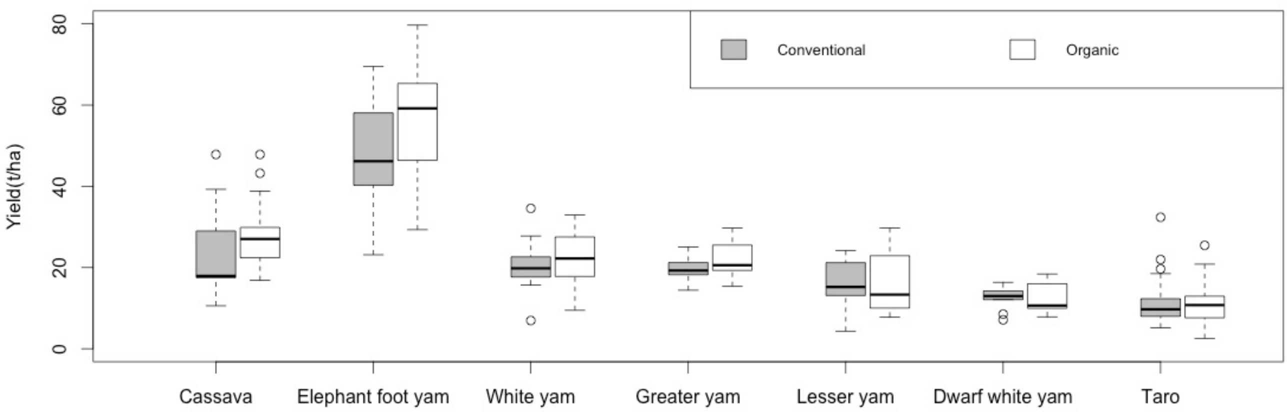

Figure 2: Distribution of yield of different crops under organic vs conventional systems

Tuber quality

The tuber quality was improved with higher dry matter, starch, crude protein, K, Ca and Mg contents under organic management. The anti-nutritional factors, oxalate content in elephant foot yam and cyanogenic glucoside content in cassava were lowered by 21 and 12.4% respectively due to organic farming.

Soil quality indicators

The water holding capacity was significantly higher under organic management (14 g cm^3) in elephant foot yam and yams over conventional practice (11-12 g cm^3). There was significant improvement in pH in organic farming (0.77, 0.46, 1.20 and 1.0 unit increase over conventional system) in elephant foot yam, yams, taro and cassava. The SOM was higher by 10-20% (Figure 3). In elephant foot yam, exchangeable Mg, available Cu, Mn and Fe contents were significantly higher in organic plots. Organic plots showed significantly higher available K (by 34%) in yams and available P in taro. The population of bacteria was higher by 41% and 23% in elephant foot yam and yams respectively. Organic farming also favoured the fungal population by 17-20%. While the N fixers showed an upper hand by 10% in organically managed soils in elephant foot yam, P solubilizers remained more conspicuous under organic management of yams (22% higher). The count of actinomycetes was favoured by 13.5% in taro. The dehydrogenase enzyme activity was higher by 23% and 14% in elephant foot yam and yams.

The Package

Use of organically produced seed materials, seed treatment in cow-dung, neem cake, bio-inoculant slurry**,** farmyard manure incubated with bio-inoculants, green manuring, use of neem cake, bio-fertilizers and ash formed the strategies for organic production. The organic farming package for elephant foot yam is included in the Package of Practices Recommendations for crops by Kerala Agricultural University (KAU, 2011).

Learning system for elephant foot yam

The learning system using ANN was designed with a learning rate and momentum coefficient of 0.6 and a tolerance value of 0.01. The output of the learning system showed about 90% agreement with the observed values. Training the ANN with more datasets can improve the predictions made by the system. The system can predict the optimum combination of organic, inorganic and environmental parameters for maximizing yield of elephant foot yam in different agroclimatic regions. Study of the environmental influence on the efficacy of organic inputs for elephant foot yam cultivation is another important application of this system.

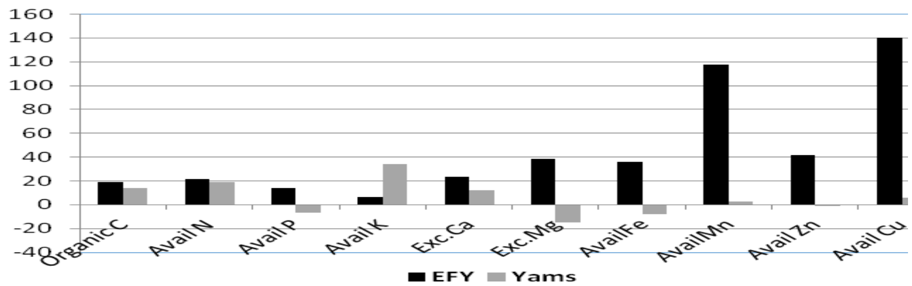

Figure 3: Percent increase or decrease in available nutrients under organic management in elephant foot yam (EFY) and yams

Discussion

Organic management enables 10-20% higher yield, quality tubers and maintenance of soil health in tuber crops. This is contrary to some of the reports that crop yields under organic management are 20–40% lower than for comparable conventional systems (de Ponti et al. 2012, Seufert et al. 2012).The higher yield in these crops may be due to the overall improvement in soil physico-chemical and biological properties under the influence of organic manures (Stockdale et al. 2001). Elimination of NH_4 fertilizers, addition of cations especially via green manure applications, decrease in the activity of exchangeable Al^{3+} ions in soil solution due to chelation by organic molecules and Ca content of the manures might have resulted in higher pH under organic management. Higher soil organic matter status of organic plots, available N, P and K under organic management was due to the direct result of inputs and constituents of various manures, especially green manure. The higher tuber quality is similar to the reports of Rembialkowska (2007) that organic crops contain more dry matter and minerals, especially Fe, Mg and P. Cost effective technologies were developed. The learning system developed will help to estimate the extent of replacement of inorganic inputs with organic manures for realizing comparable yields even without field experiments.

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